CHAPTER 12

MANUFACTURING TESTS

12.1 General

Industrial capability for the fabrication of superconducting magnets in general and thin detector solenoids in particular is sufficiently mature that this magnet does not exceed the present state of the art for such devices. However, successful performance of this magnet will depend on the selection of conservative design approaches wherever possible, and the taking of great care at every assembly stage accompanied by the performance of comprehensive testing, inspections, and measurements throughout the manufacturing process. Because it it assumed that the magnet will be procured industrially to a set of performance specifications, the specification of manufacturing tests at the outset of procurement assumes great importance.

12.2 Approval of Design

To ensure that appropriate design choices are everywhere taken the industrial procurement of this magnet system will begin with the preparation by the vendor of a comprehensive conceptual design of the system. Fermilab will review this work to ensure that it presents design choices that will result in a system that will meet specified performance criteria. One important outcome of this review will be the identification of any special testing, modeling, or other R&D that is required to confirm a particular design approach. Following the acceptance of the conceptual design by Fermilab, the vendor will deliver a complete engineering design of every element of the integrated system, accompanied with all necessary design calculations, materials selections, and assembly technique descriptions to make a full evaluation of the design by Fermilab possible. The design may be presented in logical portions, and acceptance by Fermilab of the designs of major subelements will be made project checkpoints which then pace further procurement or fabrication.

Accompanying the design of the magnet system must be the details of the assembly techniques and tooling that are required for the fabrication. Review and acceptance of these conceptual designs by Fermilab likewise will make them part of the project checkpoint schedule.

12.3 Mandatory Testing of Components

A comprehensive set of tests, inspections, and measurements will be made mandatory during the fabrication and the results of each must be documented and presented to Fermilab. Prior to the beginning of work draft plans for major tests, e.g. the conductor critical tests, must be presented to Fermilab for review and acceptance. Many of these tests, inspections, and measurements will be also be specified as the basis for project checkpoints so that until they have been successfully accomplished and reported further work cannot ensue.

When the result of any measurement, test, or inspection is a finding of noncompliance, a mechanism will be specified to resolve the issue with the knowledgeable participation of Fermilab so that rework, replacement, or repair is fully understood by Fermilab.

The minimum set of tests, inspections, and measurements that must be made by the vendor is necessarily lengthy, and subject to revision in the event that review by any cognizant Fermilab Safety Panel requires any additional testing or measurements. The adaptation to noncompliance, should it be required, may likewise generate the need for additional testing or measurement.

A representative list of mandatory tests, inspections, and measurements of components and subassemblies is presented in Table 12.1

12.4 Control Dewar and Chimney Tests at the Factory

The control dewar and attached portion of service chimney must be pre-tested at the vendor's plant before the entire system is assembled. The elements of this testing include, at a minimum those items listed in Table 12.2.

12.5 Fully Integrated System Tests at the Factory

The fully integrated system then must be comprehensively tested prior to disassembly and shipment. A full checkout of the energization, logging, and protection system provided for the tests must be made prior to cooldown of the system. The system tests will include cooldown and operation of the system with specified charging and discharging schedules, and include the logging of a comprehensive list of data sensors from the magnet system. The goals of these tests are to demonstrate full suitability of the system to perform as specified. Fermilab will witness these tests, itemized in Table 12.3.

12.6 System Acceptance Tests at Fermilab

As part of final acceptance by Fermilab the system must be fully tested after it is received and installed in the DØ detector. Prior to the conducting of these tests, the Fermilab energization/protection/control system will be fully tested and debugged. The operation of the Fermilab refrigeration system will be likewise tested prior to installation of the magnet.

Preliminary inspections and measurements for shipping damage must be done upon receipt of the magnet system components at Fermilab. The magnet system tests to be made after the system is fully installed closely follow those originally done by the vendor as detailed in section 12.5 above.

12.7 Magnetic Field Mapping

A complete and accurate field map will ultimately be desired for the magnet after it is installed in the DØ detector. In general, the measurement of field values on a cylindrical surface just inside the inner shell of the magnet cryostat, and on the ends of the cylindrical volume, is sufficient to fully predict the field everywhere in the bore of the magnet [1]. At present it is not clear how much influence the toroid system will have on the shape of the field of the solenoid; ultimately it will be necessary to map the solenoid field with the toroids fully closed and powered. The limited access to the bore of the solenoid when the EF toroids are closed will complicate this mapping. Tracking studies suggest that the calculated field shape, perhaps adjusted where practical by measurements of limited precision, might be sufficient for initial physics data taking if time does not exist for a more comprehensive mapping effort. The CDF detector had not begun to use the results of its field mapping [2] until several years' operation of the detector had elapsed.

For normalization purposes, especially because the field may periodically be reversed, it may be desirable to install several hall probes in select locations in the tracking volume of the magnet.

References

[1] H. Wind, "Where Should a Magnetic Field be Measured?", IEEE Transactions on Magnetics, Vol **MAG-5**, No.3, Sept. 1969, pp 269-270.

[2] C. Newman-Holmes, E.E. Schmidt, R. Yamada, "Measurement of the Magnetic Field of the CDF Magnet," Nuclear Instruments and Methods in Physics Research, **A274**, 1989, pp 443-451

Table 12.1: Component Testing	
Item	Test/Inspection/Measurement
1	Superconductor strand critical current measurement
2	Superconductor strand filament inspection
3	Superconducting cable critical current measurement
4	Strand ID and cold weld map in cable
5	Aluminum superconducting cable bond measurement
6	Cable placement and overall tolerances of finished conductor
7	Finished conductor Short sample critical current measurement
8	RRR and yield strength of aluminum stabilizer in conductor
9	Inspection and measurement of winding mandrel
10	Conductor length ID in coil winding
11	Continuous monitoring of winding tension, conductor insulation, and measurement of turn location during winding
12	Inspections and measurements during joint-making
13	High potential tests of coil to ground
15	Inspection and measurement of outer support cylinder
16	Inspections and measurements during installation of cylinder
17	Inspections and measurements during vacuum impregnation and/or epoxy cure of coil
18	High potential tests of finished coil to ground
19	Inspections and measurements of radiation shields
20	Inspections, tests, and measurements of cold mass support links
21	Pre-installation testing of all instrumentation sensors
22	Inspections and measurements of vacuum vessel shells
23	High potential testing of installed cold mass
24	Leak and vacuum testing of magnet cryostat
25	Inspections and measurements of service chimney components
26	Inspections and measurements of the superconducting buses
27	Leak, high potential, and vacuum testing of service chimney
28	Inspections and measurements of control dewar components
29	Leak, high potential, and vacuum testing of control dewar

Table 12.2: Control Dewar/Chimney Pretests	
Item	Test/Measurement
1	Pressure and flow tests of all internal piping
2	Tests of all reliefs, check valves
3	High potential tests and measurements
4	Cooldown tests and measurements
5	Heat leak measurements
6	High potential tests and measurements
7	Comprehensive tests of vapor cooled current leads
8	Tests of all pertinent instrumentation

Table 12.3: System Testing	
Item	Test/Inspection/Measurement
1	Pressure and flow tests
2	High potential tests and measurements
3	System cooldown tests and measurements
4	Charging and discharging of system with data logging
5	Operation at design current for specified duration
6	Operation at specified overcurrent
7	Fast and slow discharge tests
8	Quench tests from loss of coolant flow